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(73) Proprietor: **PHARES PHARMACEUTICAL HOL-
LAND B.V.**
Tesselschadestraat 4-12 P.O. Box 75001
NL-1070 Amsterdam(NL)(72) Inventor: **Leigh, Steven c/o Stevens, Hewlett
& Perkins**
5, Quality Court, Chancery Lane
London WC2A 1HZ(GB)(74) Representative: **Gaunt, Robert John et al**
Stevens, Hewlett & Perkins 1 Serjeants' Inn
Fleet Street
London EC4Y 1LL(GB)

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EP 0 158 441 B1

Description

This invention relates to pro-liposome compositions based on membrane lipids, to a method of making lipid vesicles by the addition of aqueous liquid to these compositions, and to aqueous dispersions of the vesicles. Membrane lipids are lipids which form bilayers with water; they are chiefly phospholipids such as lecithin and related materials such as glycolipids. Phospholipid vesicles are also known as liposomes. According to the general nomenclature, all types of lipid bilayers surrounding an aqueous space are generally known as liposomes. An article by R. Firfield in New Scientist, 16th October 1980, pages 150 to 153 describes the preparation of liposomes from membrane lipids and says:-

".....Liposomes are microscopic bags (vesicles) that function like a cell membrane. Although liposomes are artificial entities, they display some biological properties, and as such they seem to be accepted into the environment of living cells. Some may merge with the cells own membrane and even function as if they were themselves organelles.....so we can use liposomes to incorporate a wide range of materials that we choose to introduce into the cell, including medicines that can be accurately targeted to the site where they will have the greatest and most useful effect. Moreover, the wrapping material is biodegradable."

The promise held out by liposomes as a means of delivering and targeting drugs has, not surprisingly, prompted intensive research into this subject. However, difficulties have arisen which have hindered the commercial utilization of the valuable properties of liposomes. These difficulties are in summary:-

1. Liposomes made by conventional techniques tend to be large multi-lamellar vesicles which contain only a relatively small volume of entrapped aqueous liquid. The concentration of drug (or other material) that can be introduced into such vesicles is seldom high enough to be useful.

2. Techniques are known for making liposomes in the form of unilamellar vesicles with large void volumes. But such techniques generally require complex equipment and careful control of conditions, and are not well suited to commercial operation.

3. Existing liposome dispersions are often unstable on storage, due to leakage and mechanical breakdown of the vesicles in suspension.

Some methods have been described in the literature aimed at improving the formation and entrapment efficiency of liposomes. Reference is drawn to a review on this subject by Szoka and Papahadjopoulos in "Liposomes: From Physical structure to Therapeutic Applications", Knight (ed.) Elsevier/North - Holland Biomedical Press, 1981, chapter 3. Three categories of liposome may be distinguished:-

- i) Multi-lamellar vesicles comprise a whole series of concentric bilayers of membrane lipid with aqueous medium between the bilayers. They may be formed by dissolving a membrane lipid in an organic solvent, removing the solvent by evaporation to leave the lipid as a thin film, e.g. on the wall of a round bottom flask. Addition of aqueous buffer with agitation results in eventual formation of liposomes of various sizes up to 30 microns diameter. Because of the large number of bilayers in each vesicle, the amount of aqueous fluid entrapped is relatively small, of the order of 1 to 4 litres per mole of lipid, and drug entrapment ratios are rather low, less than 20%. Vesicle size can be reduced by sonication, but this does not increase the entrapment ratio.

- ii) More vigorous sonication of multi-lamellar vesicles (MLV) results in the formation of small unilamellar vesicles (SUV), typically having diameters of 20 to 50 nm. SUVs can also be formed by rapid injection of a dilute solution of lipid in ethanol (maximum 3% by weight lipid) into an aqueous phase. SUVs typically have an aqueous void volume of from 0.2 to 1.5 litres per mole of lipid, and a drug entrapment ratio below 1%, far too low to be commercially useful.

- iii) Large unilamellar vesicles (LUV) may be formed by injecting a dilute solution of lipid in ether into aqueous fluid. Unlike the ethanol injection technique, the lipid concentration in the organic solvent does not appear to affect the size of the resulting liposomes. Thus this technique can give rise to vesicles having diameters in the range 0.15 to 0.25 microns and having an aqueous void space of 8 to 17 litres per mole of lipid. However, the drug entrapment ratio, at less than 1%, is still far too low to be useful.

LUVs can also be formed from water-in-oil emulsions of phospholipid and buffer in an excess organic phase, followed by removal of the organic phase under reduced pressure. This technique is reported to result in LUVs having diameters in the range 0.17 to 0.8 microns, void volumes in the range 4 to 14 litres per mole of lipid and drug entrapment ratios of 20 to 60%. But the preparative technique is difficult, requires complex equipment, and is not well suited to large-scale commercial operation.

In EPA 69307 there is described a method of producing liposome solutions by subjecting an aqueous solution of phospholipid to ultra-sonic radiation in the presence of an inert volatile solvent or gas. In Example 1, a solution of phospholipid in ethanol is subjected to ultra-sonic radiation on the addition of a

large excess of water, and the aqueous dispersion subjected to further prolonged (75 minutes) ultra-sonic radiation. The method involves very vigorous treatment such as would not be practicable in commercial operation, and gives rise in our hands to dispersions of liposomes having low drug entrapment values.

EP-A-0130577 discloses a method for producing liposomes which comprises mixing liposome membrane components with a water-soluble non-volatile solvent and, then, dispersing the mixture in an aqueous medium. Examples of the water-soluble non-volatile solvent are given as polyhydric alcohols, glycerin esters and benzyl alcohol.

This invention seeks to avoid the problems of the prior art. It provides a pro-liposome composition, and a method of converting this to an aqueous liposome dispersion by simple addition of aqueous fluid with agitation. In the resulting liposome dispersion, which forms another aspect of the invention, the liposomes are generally oligo- or multi-lamellar vesicles with a void volume of at least 2 ml per gram of lipid, and capable of achieving a drug entrapment ratio of more than 20%, under preferred conditions more than 40%. The composition may also be provided in sprayable form to form an aerosol of droplets which, on contact with aqueous media, spontaneously form liposome dispersions.

The invention provides a pro-liposome composition comprising a uniform mixture of:-

- a) at least one membrane lipid,
- b) at least one water-miscible organic solvent, and optionally
- c) an amount of water,

such that, on addition of excess water, the composition spontaneously forms vesicles or liposomes, the proportion by weight of a) to b) being from 40:1 to 1:20.

In one specific embodiment, the invention provides a pro-liposome composition comprising a uniform mixture of:-

- a) at least one membrane lipid,
- b) at least one water-miscible organic solvent selected from ethanol, isopropyl alcohol, methanol and butanol, and optionally
- c) an amount of water,

such that, on addition of excess water, the composition spontaneously forms vesicles or liposomes, the proportion by weight of a) to b) being from 40:1 to 1:20.

The invention further provides a pro-liposome composition comprising a uniform mixture of:-

- a) at least one membrane lipid and
- b) at least one water-miscible organic solvent,

the proportion by weight of a) to b) being from 40:1 to 1:20, which upon the addition of a small amount of water forms a network of expanded bilayers, addition of further water leading to the entrapment of water inclusions within the said bilayers and addition of excess water and optionally agitation leading to the breakdown of this structure to form vesicles or liposomes. In one specific embodiment, the water-miscible organic solvent is selected from the group consisting of ethanol, isopropyl alcohol, methanol and butanol.

These compositions are progenitors of liposomes, or pro-liposomes. In another aspect, the invention also includes a method of forming an aqueous dispersion of liposomes, which method comprises mixing the dilutable pro-liposome composition with excess water. The excess water is preferably added in two stages and at elevated temperature and the liposomes are formed upon subsequent cooling to ambient temperature.

In a further aspect, the invention also provides an aqueous liposome dispersion comprising liposomes formed of membrane lipid which have diameters in the range of 0.1 to 2.5 μm and contain at least 2 ml of entrapped aqueous fluid per gram of the lipid, characterized by the presence in the aqueous dispersion of detectable quantities of at least one water-miscible organic solvent.

The compositions of this invention may be presented in sprayable form. As a particularly advantageous aspect of this, the invention further provides an aerosol composition comprising in a volatile liquid propellant:-

- a) at least one membrane lipid,
- b) at least one water-miscible organic solvent, and optionally
- c) up to 40%, by weight on the combined weights of a), b) and c), of water,

such that, on coming into contact with excess water, the composition spontaneously forms vesicles or liposomes, the proportion by weight of a) to b) being from 40:1 to 1:20. These will be referred to hereafter as aerosol compositions. In another aspect, the invention provides a method of making an aqueous dispersion of liposomes which comprises spraying an aerosol composition so that it comes into contact with excess water. In one specific embodiment, the water-miscible organic solvent is selected from the group consisting of ethanol, isopropyl alcohol, methanol and butanol.

Suitable membrane lipids are phospholipids, for example natural lecithins such as soy lecithin and egg yolk lecithin and synthetic lecithins e.g. di-palmitoyl phosphatidyl choline. Other materials such as glycolipids may be used. When the liposome dispersion is destined for internal medical use, the lipid must naturally be of pharmaceutically acceptable quality. When this is not the case, it is possible to use phospholipids of analytical grade or lower.

Indeed, cheaper grades of phospholipid are sometimes easier to disperse in water than the chromatographically purified materials, and may be preferred for this reason. This is in contrast to the prior art which has generally considered it necessary to use highly purified lipid materials.

Other membrane lipids that can be used include long-chain dialkyl dimethyl ammonium compounds for example di-stearyl dimethyl ammonium compounds such as di-stearyl dimethyl ammonium chloride, and di-tallow dimethyl ammonium compounds such as di-tallow dimethyl ammonium chloride. These are synthetic materials which have the advantage of constant quality over lecithins and other naturally occurring materials, and are also less prone to oxidation.

When the compositions of this invention are intended for pharmaceutical use, component b) needs to be non-toxic. Component b) is preferably an aliphatic alcohol such as glycerol, propylene glycol, or, particularly, ethanol. Isopropyl alcohol, methanol, butanol and ethylene glycol may also be used when appropriate.

In the dilutable pro-liposome compositions, the proportion of component a) to component b) is from 40:1 to 1:20, preferably from 10:1 to 1:5, particularly from 2:1 to 1:2, by weight. Component b) assists in the rapid formation of the liposomes, perhaps by influencing the hydration of the polar head groups of the membrane lipids. It also improves the entrapment efficiency of the system. If too little of component b) is present, the switch-over to form liposomes on addition of water may be slow and the entrapment efficiency may be low. If too much of component b) is present, the composition becomes a dilute solution of membrane lipid in organic liquid, which merely wastes organic liquid and reduces entrapment efficiency. On addition of excess water to the composition, component b) mainly becomes dissolved in the continuous phase and plays no further part in the system.

The pro-liposome compositions preferably contain from 5% to 40%, particularly from 5% to 20%, by weight of water. Water serves two useful functions. First, the right proportion of water can enhance the spontaneity of liposome formation, when excess water is added, and can influence the liposome size and the entrapment efficiency of the system. Second, water can act as a carrier or solvent for a drug intended to be trapped in the inner water phase of the liposomes.

Particularly preferred dilutable pro-liposome compositions comprise from 35 to 55% by weight of component a), from 30 - 55% by weight of component b), and from 5 to 20% by weight of water. The compositions are readily diluted with water to form liposome dispersions of high entrapment efficiency.

The aerosol compositions of this invention generally contain from 5% to 40%, preferably 10% to 20%, of membrane lipid component a); up to 40%, preferably up to 10%, of water component c); balance ethanol or other water-miscible solvent, all percentages being by weight on the combined weights of components a), b) and c). Water is not critical to promote liposome formation as the pro-liposome is discharged as fine droplets, but may be useful when a water-soluble biologically active material is to be included. When ethanol is used as component b), a minor proportion of propylene glycol or glycerol may be included to reduce possible volatility problems which might arise on spraying. Indeed, propylene glycol or glycerol may be used in partial or complete replacement for ethanol. The proportion by weight of membrane lipid component a) to water miscible solvent component b) is preferably from 1:2 to 1:10.

The aerosol compositions include a volatile liquid propellant which is preferably a perhalocarbon such as Arcton 12 (CCl_2F_2) or Arcton 114 ($\text{C}_2\text{Cl}_2\text{F}_4$). Butane may be used in circumstances where its use is permitted. The propellant generally constitutes from 50% to 95%, usually 60% to 80%, by weight of the overall composition. When a precisely metered dose of biologically active material has to be delivered, the proportion of propellant will generally be towards the upper end of this range.

On being sprayed, e.g. from an aerosol container, the propellant rapidly volatilises, leaving an aerosol of the remaining components as a pro-liposome composition in the form of droplets of a size determined by the spray nozzle and preferably below 8 microns. On contacting water, these droplets spontaneously form a dispersion of liposomes which constitute very effective drug carriers. This aspect of the invention is thus particularly suitable for aerosols for treating asthma, bronchitis or other respiratory tract problems. Examples of drugs which may be incorporated in the sprayable compositions of this invention are salbutamol, terbutaline, orciprenaline, isoprenaline, reproterol, pirbuterol, budesonide, beclomethasone, di-propionate, sodium chromoglycate, fenoterol, ipratropium, beta-methasone valerate, rimiterol, theophylline and ketotifen.

The pro-liposome compositions and the sprayable compositions of this invention may contain other non-volatile components in addition to a), b) and c). In particular, it is preferred to include up to 25% by weight [on the combined weights of components a), b) and c)] of a fatty acid ester such as glyceryl tripalmitate or a sorbitan fatty acid ester, for example one of the materials sold under the name SPAN (a Registered Trade Mark). There is evidence that from 5 to 15% by weight of SPAN tends to increase entrapment efficiency by increasing void volume, and this effect is particularly marked when the cheaper grades of membrane lipid are used. While the reason for this effect is not understood, the fact that SPAN is particularly effective in samples subjected to excessive agitation suggests that the SPAN may also strengthen the liposomes in some way.

Cholesterol and other natural and synthetic vegetable fats and oils are conventionally added to liposome preparations, and may be included if desired in compositions according to this invention as replacements for up to about half the membrane lipid. High HLB surfactants, such as the range of materials sold under the Trade Mark TWEEN are not necessary and are not preferred, but may be included in compositions of this invention to counteract aggregation of liposomes in aqueous dispersion in amounts up to 1 to 2% by weight of components a), b) and c). Small quantities of materials which alter the net balance of charges, e.g. stearylamine and di-cetyl phosphate may also be included for this purpose in amounts up to about 20% by weight of components a), b) and c). Additives such as cholesterol, stearylamine, and cetyl phosphate may also improve liposome stability.

The liposome dispersions of this invention have pharmaceutical uses, for both internal and external application. They also have potential value in other fields, such as diagnostics, insecticides and horticulture. In recent years there has been increasing interest in the use of liposomes as carriers of compounds which are of interest because of one or other biological property, for example medicaments, proteins, enzymes, hormones, vitamins and marker compounds. It is to be understood that this broad group of biologically interesting compounds, which includes medicaments (human and veterinary) but is not restricted thereto, will be referred to in this specification as "biologically active compounds". In most cases, a biologically active compound needs to be included in a dilutable or aerosol composition. How this is done, in order to achieve maximum entrapment efficiency in the resulting liposome dispersion, depends on the properties of the active ingredient. Ingredients which are oil-soluble are best dissolved in the mixture of components a) and b). Ingredients which are insoluble may be dispersed, in the form of particles of sub-micron size, in the mixture of components a) and b). Ingredients which are water-soluble may be added as a concentrated aqueous solution to the mixture of components a) and b). The compositions of this invention are preferably prepared by first dissolving the membrane lipid in the organic solvent. This may be done at ambient or elevated temperature, preferably under nitrogen. Any other lipophilic components, e.g. SPAN or lipophilic drugs, should be added at this stage, then the required amount of water is added, and the mixture equilibrated. The term water is used here to include aqueous fluids, such as buffered solutions and solutions of active ingredients. Where a hydrophilic drug is being added, this should preferably be done by adding a solution of the ingredient in the minimum amount of water. After equilibration of this mixture, additional water may be added to provide a pro-liposome composition.

The pro-liposome compositions are mostly clear liquids at elevated temperatures around 50 to 60°C. Depending on their water content, some compositions show phase separation when cooled to ambient temperature. This phase separation is not harmful, and may even ease dispersion to form liposomes on addition of excess water. On addition of excess water (which term is again used to cover aqueous fluids, such as buffer solution) phase rearrangement takes place and a liposome dispersion is formed. Little or no agitation is required, although some limited agitation may improve dispersion. Excessive agitation may break up liposomes and reduce entrapment efficiency. Addition of excess water may be made at ambient or elevated temperatures, although dispersion may be quicker and easier at ambient temperature. Alternatively a fluid pro-liposome composition of this kind can be converted into a liposome dispersion by being sprayed into aqueous environment.

In most cases, economic considerations require that the method be performed to prepare liposomes that provide the highest possible entrapment of a limited amount of active ingredient (e.g. drug). Various conditions have to be optimised in order to maximise drug entrapment; pro-liposome preparation; dilution regimen; control of osmotic balance inside and outside the liposome; choice of membrane lipid; use of surfactants/stabilisers; modification of surface charge balance, etc. Lipid-drug ratios of 5:1 or less should be achievable using such approaches without too much difficulty.

In other cases, e.g. when the drug is cheap or readily reclaimable, entrapment efficiency may not be critical. In such cases, much higher levels of drug may be used, or the drug may be incorporated with the buffer used to form the liposome dispersion from the pro-liposome composition. If required, excess drug can be removed or recovered by filtration, dialysis or centrifugation.

The great majority of the resulting vesicles in the liposome dispersion have diameters within the range of 0.1 to 2.5 μm . The mean particle size generally averages out at 0.2 to 0.7 μm , and if further size reduction is desirable, the dispersion may be extruded through a membrane filter. The vesicles are often found to form two populations; a population of large particles having a mean diameter of about 1.8 μm and containing about one third of the entrapped aqueous fluid although the number of such particles is only about 5% of the total number; and a population of small particles having a mean diameter of about 0.2 microns and containing about two thirds of the entrapped aqueous fluid. The vesicles generally contain a few lipid bilayers and entrap at least 2ml, and often 4 ml to 8 ml, of aqueous fluid per gram of membrane lipid. Void volumes herein have been measured by a standard procedure involving the addition of radioactively labelled inulin to the aqueous liposome dispersion. These liposome dispersions are characterized by containing detectable quantities of a water-miscible organic liquid which is a solvent for the lipid, namely component b) of the starting pro-liposome or sprayable composition. Most liposome dispersions of the prior art do not contain any water-miscible organic liquids. Those that do, (e.g. those formed by the ethanol injection technique and according to EPA 69307) comprise vesicles of small size and small void volume.

A particularly attractive feature of this invention is that it may be applied to preparations for oral administration. For example, a pro-liposome composition may be placed inside a capsule which is then swallowed whole. Depending on the design of the capsule, the contents will be released somewhere in the gastrointestinal tract to form vesicles in-vivo. The drug remains protected within the lipid bilayers of the vesicles. It has been suggested that protecting a poorly absorbed, labile drug (e.g. insulin) in this manner could help absorption. In this connection, it has been noted that vesicles can form, irrespective of the ionic strength of the aqueous environment, in the range pH 3.2 to 8.6. It is assumed that any "free" drug remaining in the aqueous environment after spontaneous vesicle formation is non-toxic and need not be removed. Alternatively, the liposome dispersion can be generated in-vitro. Because of the simple preparative method, the dispersions can often be prepared immediately prior to use. This avoids a problem inherent in prior art liposome dispersions, namely poor storage stability. However, liposome dispersions according to this invention have shown good storage stability.

Reference is directed to the accompanying drawings, in which:-

- Figure 1 is a three-phase diagram for lipid/alcohol/water (L:A:W) showing regions yielding liposome dispersions having high glucose entrapment efficiency.
- Figure 2 Freeze-fracture electron micrographs of replicas of liposomes prepared from formulation (L:A:W/50:40:10).
- Figure 3. Diagrammatic representation of the steps involved in the formation of liposomes from pro-liposome compositions.

The following Examples illustrate the invention.

Example 1

1. General Methodology and Nomenclature

Liposomes were prepared using the pro-liposome technique. This technique involves the addition of water to pro-liposome compositions prepared by combining lipid (lecithin), ethyl alcohol and water in appropriate ratios. These mixtures contained 5% (w/w) of glucose to act as a model for a water-soluble drug. The different formulations tested are identified by their basic proportions by weight of lecithin (L), alcohol (A) and water (W) e.g. (L:A:W/50:40:10). In all cases 10% (w/w) SPAN was added, and this component is considered to be additional to the basic formulation and its presence indicated separately.

2. Preparation of Pro-Liposome Compositions

Pro-liposomes were made up in 1 - 5 g batches. The appropriate weight of lecithin required to yield the desired formulation was first dissolved in the corresponding amount of alcohol at about 50 to 60°C under N_2 . The water fraction was then added in two parts. The first part consisted of the appropriate amount of glucose solution (500 mg/ml) required to yield a 5% (w/w) concentration of glucose and the second part the amount of distilled water required to make up the final formulation. 100 mg of SPAN per gram of formulation was added together with the lecithin. A typical formulation for 1 g of (L:A:W/50:40:10) plus 10% SPAN, would thus contain

- 500 mg lecithin (BDH egg-yolk)
- 400 mg (500 μl) ethyl alcohol

100 mg (100 μ l) glucose (500 mg/ml) aqueous solution

100 mg SPAN

The pro-liposome compositions were equilibrated for a further 15 minutes under N₂ before moving to the liposome formation stage.

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3. Preparation of Liposomes

Following equilibration, the pro-liposome compositions were cooled to 25°C. The liposomes were then prepared by a two-stage addition of 50 mM phosphate buffer (pH 7.4). In the first stage, 4 ml of buffer was added (per 1.1 grams of pro-liposome composition containing 10% SPAN). This addition was made dropwise and the sample was vigorously hand-shaken both during the addition and for 1 minute following the addition. The sample was then allowed to equilibrate for 30 minutes at 25°C with further 1 minute periods of shaking after 15 and 30 minutes. The second addition of buffer, consisting of 6 ml of buffer per gram pro-liposome composition, was made at this stage and the sample equilibrated at 25°C for a further 30 minutes. Again it was hand-shaken for 1 minute every 15 minute.

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4. Measurement of Entrapment Efficiency

The efficiency of entrapment, calculated as the percentage of glucose added to the formulation retained within the liposomes, was estimated by separating the liposomes from excess untrapped glucose using a gel-filtration column and measuring the proportions of free and trapped glucose enzymatically.

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Aliquots of 0.5 ml of liposome dispersion were passed down a filtration column (20 cm long x 1.0 cm diameter) containing Sephadex G-50 (fine) (Sephadex is a Registered Trade Mark) equilibrated with 50 mM phosphate buffer (pH 7.4). The liposomes were eluted using the same buffer. The liposome fraction, which was easily identified by its opalescence, was collected first and usually consisted of some 5 ml. A series of 3 ml fractions were collected after elution of the liposomes for analysis for free glucose.

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5. Entrapment Efficiencies

The results of a typical series of measurements carried out using a wide range of formulations are listed in Table 1.

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These were performed using ethanol. But it can be predicted that similar patterns will be found with other water miscible liquids, albeit with somewhat higher entrapment ratios, as indicated in Examples 16 to 19. Mixtures of solvents can be used. When using solvents of higher molecular weight than ethanol, it may be found that more solvent is required (than would be the case when using ethanol) to ensure spontaneous liposome formation.

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Table 1

Entrapment efficiencies of a series of different pro-liposome formulations		
	Formulation* (L:A:W)	Entrapment Efficiency
5	54 : 35 : 11	45%
	55 : 35 : 10	41%
	50 : 40 : 10	41%
10	45 : 40 : 15	36%
	40 : 20 : 40	35%
	50 : 35 : 15	34%
	50 : 37.5 : 12.5	34%
	40 : 50 : 10	30%
15	40 : 45 : 15	30%
	54.5 : 36.5 : 9	29%
	45 : 45 : 10	28%
	50 : 12.5 : 37.5	28%
	50 : 10 : 40	28%
20	40 : 40 : 20	28%
	40 : 30 : 30	26%
	50 : 25 : 25	25%
	50 : 30 : 20	24%
	40 : 10 : 50	22%
25	60 : 30 : 10	22%

* All samples contained 10% (w/w) SPAN

The collected results of a series of such experiments have been used to plot the three-phase diagram of entrapment efficiency shown in Figure 1. In this figure, region 1 denotes compositions yielding liposomes characterized by 40 - 50% glucose entrapment. Regions 2, 3 and 4 denote compositions which achieve 30 - 40%, 20 - 30% and below 20% glucose entrapment respectively. The reproducibility of results was good ($\pm 5\%$) using a given batch of BDH egg-yolk lecithin but inter-batch variations were encountered.

Interest has been concentrated on the liposomes formed from the (L:A:W/50:40:10) formulation. There is, however, no reason to suspect that liposomes formed from other formulations are different in structure. Typical electronmicrographs of freeze-fracture replicas of liposomes are shown in Figures 2a - c. The liposomes are normally 0.15 - 2.5 μ in diameter and appear to consist of three or four bilayers around a central aqueous core. Cross-fracture views of liposomes indicate that they contain large enclosed aqueous volumes (Figure 2c).

6. Sequence of Events Involved in Liposome Formation

The sequence of events following the addition of water (or buffer) to pro-liposome compositions has been examined using ^{31}P n.m.r. and electron microscopy. Most of the formulations used are clear liquids at elevated temperatures (50 - 60°C). Formulations containing little water remain clear when cooled to 25°C but those with appreciable water ($\geq 40\%$) tend to phase-separate. Depending on the rate of cooling this leads to the separation of a clear gel (slow cooling) or a fudge-like precipitate (rapid cooling). Mild agitation leads to a uniform consistency paste in both cases.

A similar phase-separation process occurs if excess water is added to the pro-liposome compositions at 25°C. ^{31}P n.m.r. measurements indicate that this separation corresponds to the formation of lipid bilayers. Precipitation of bilayer phase occurs following the addition of 30 - 40% (w/w) of water. Freeze-fracture electron microscopy indicates that the bilayers form as stacks and there is little indication of liposome formation. Pockets of liposomes are found in the freshly precipitated samples but they are comparatively rare. Addition of more water and agitation leads to formation of liposomes in the normal way. Few liposomes, however, are seen in samples containing less than 50 - 60% water.

A scheme illustrating the steps that appear to be occurring in liposome formation is presented in Figure 3. The pro-liposome solution is normally a clear liquid (a), addition of small amounts of water leads to the formation of a network of expanded bilayers (b), further additions lead to the entrapment of water inclusions within the bilayers (c) and agitation leads to the breakdown of this structure to form liposomes (d). This

scheme, which is consistent with the results of the n.m.r. and electron microscopy studies, accounts for the fact that the liposomes formed by the pro-liposome technique contain large aqueous spaces and tend to involve few thicknesses of bilayer. The role of the water-miscible organic liquid in this process is to ensure that the lipid initially precipitates as a loose network and to allow efficient penetration of excess water. The sequence of events will necessarily vary somewhat with different formulations of pro-liposomes. Samples with very high lipid concentrations will not go into solution easily and bilayer precipitation will lead to tightly packed bilayer stacks not easily penetrated by water. Samples containing high water contents will tend to be close to the final liposome stage whilst samples with very high alcohol content will be difficult to precipitate without using excessive quantities of water.

The pro-liposome method of the invention provides an exciting method of preparing large volumes of liposomes from cheap ingredients using simple technology. The liposomes formed by this method have large internal volumes and are ideal for the encapsulation of drugs. Incorporation of the drug in the pro-liposome composition allows high (30 - 40%) drug encapsulation with the minimum of wastage. Alternatively, if the drug is cheap and high entrapment efficiency is not required, the drug can be added together with the aqueous phase used in the formation of the liposome from the pro-liposome composition. Excess drug can then be removed, by filtration, dialysis or centrifugation leaving liposomes containing high concentrations of active ingredients.

Examples 2 to 6

The following sprayable compositions were made up:-

Component	Concentration (wt%)				
	Ex.2.	Ex.3.	Ex.4.	Ex.5	Ex.6
Egg yolk lecithin	20	15	20	15	15
Span 40	5	-	-	-	-
Water	10	10	20	-	10
Butylated hydroxytoluene	0.1	0.1	0.1	0.1	0.1
Theophylline	-	1.0	-	-	1.0
Salbutamol	-	-	0.25	-	-
Beclomethasone	1.0	-	-	1.0	-
Propylene glycol	-	10	-	10	73.9
Absolute alcohol	63.9	63.9	59.65	73.9	-

One part by weight of the Example 2 or Example 5 formulation was mixed with 9 parts by weight of Arcton 12. An aerosol metering valve of 100 microlitre capacity delivered 100 micrograms of beclomethasone per dose.

Two parts by weight of the Example 3 or Example 6 formulation was mixed with 8 parts by weight of a mixture of Arcton 12 and Arcton 114. A 100 microlitre dose contains 200 micrograms of theophylline.

4 parts by weight of the Example 4 formulation was mixed with 6 parts by weight of Arcton 12. A 100 microlitre dose contains 100 micrograms of salbutamol.

Examples 7 to 13

The procedure of Example 1, as described above in numbered paragraphs 1 to 4, was repeated using different drugs and different pro-liposome formulations. Except where stated below, the following standard pro-liposome formulation was used:-

Egg yolk lecithin	500 mg
Span 40	100 mg
Ethyl alcohol	400 mg
Water containing drug	100 mg

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In all cases, centrifugation was used instead of gel-filtration to separate the two phases of the liposome suspension. The suspension was centrifuged at 100,000 G for 45 minutes. The supernatant liquid was assayed for drug content. The weights of the supernatant liquid and of the precipitate were recorded and the % of drug associated with the precipitate (% retention) calculated.

Example 7

Drug Retention	Glucose, at 25 and 250 mg/ml 18%
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Example 8

Drug Retention	Tetracycline, at 6 and 60 mg/ml 43%
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Example 9

Drug Retention	Carbocysteine, at 1 mg/ml 23%
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Example 10

Drug Retention	p-Aminobenzoic acid, at 5 mg/ml 23%
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Example 11

Drug Retention	Theophylline, at 5.9 mg/ml 24%
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Example 12

Drug Membrane lipid Retention	Theophylline, at 5.9 mg/ml Distearyl dimethylammonium chloride used in place of egg yolk lecithin 20%
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Example 13

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Drug	Theophylline, at 5.9 mg/ml
Pro-liposome formulation	Span 40 omitted
Retention	22%

10 Example 14 to 18

The procedure of Example 1, as described above in numbered paragraphs 1 to 4, was repeated using different pro-liposome formulations. Glucose was used to represent a drug. % retention of glucose was measured by dialysis.

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Example 14

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Formulation	Egg yolk lecithin	280 mg
	Cholesterol	140 mg
	Dicetyl phosphate	80 mg
	Ethyl alcohol	400 mg
	Water containing drug	100 mg
Drug	Glucose, at 100 mg/ml	
Retention	32%	

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30 Example 15

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Formulation	Egg yolk lecithin	450 mg
	Glyceryl tripalmitate	90 mg
	Ethyl alcohol	370 mg
	Water containing drug	90
Drug	Glucose, at 100 mg/ml	
Retention	22%	

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Example 16

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Formulation	Egg yolk lecithin	500 mg
	Ethylene glycol	400 mg
	Water containing drug	100 mg
Drug	Glucose at 100 mg/ml	
Retention	30%	

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Example 17

Formulation	Phosphatidyl choline Ethyl alcohol Water containing drug	500 mg 400 mg 100 mg
Drug Retention	Glucose at 500 mg/ml 40%	

Example 18

Formulation	Egg yolk lecithin Propylene glycol Water containing drug	500 mg 400 mg 100 mg
Drug Retention	Glucose at 100 mg/ml 35%	

Example 19

Formulation	Egg yolk lecithin Isopropanol Water containing drug	500 mg 400 mg 100 mg
Drug Retention	Glucose at 100 mg/ml 36%	

Claims

Claims for the following Contracting States : DE, FR, GB, IT

1. A pro-liposome composition comprising a uniform mixture of:-
 - a) at least one membrane lipid,
 - b) at least one water-miscible organic solvent selected from ethanol, isopropyl alcohol, methanol and butanol, and optionally
 - c) an amount of water,
 such that, on addition of excess water, the composition spontaneously forms vesicles or liposomes, the proportion by weight of a) to b) being from 40:1 to 1:20.
2. A pro-liposome composition comprising a uniform mixture of:-
 - a) at least one membrane lipid,
 - b) at least one water-miscible organic solvent, and
 - c) water in an amount less than that which results in formation of liposomes,
 such that, on addition of excess water, the composition reorganises into vesicles or liposomes, the proportion by weight of a) to b) being from 40:1 to 1:20.
3. A composition according to claim 1 or 2, containing a small amount of water resulting in the formation of a network or stack of expanded bilayers, the composition reorganising into liposomes on addition of excess water.

4. A composition according to claim 1, containing water resulting in the formation of bilayers with water inclusions entrapped within said bilayers, the composition reorganising into liposomes on addition of excess water.
5. A pro-liposome composition comprising a uniform mixture of:-
 - a) at least one membrane lipid and
 - b) at least one water-miscible organic solvent selected from ethanol, isopropyl alcohol, methanol and butanol,the proportion by weight of a) to b) being from 40:1 to 1:20, which upon the addition of a small amount of water forms a network or stack of expanded bilayers, addition of further water leading to the entrapment of water inclusions within the said bilayers and addition of excess water and optionally agitation leading to the breakdown of this structure to form vesicles or liposomes.
6. A pro-liposome composition in anhydrous form comprising a uniform mixture of:-
 - a) at least one membrane lipid, and
 - b) a mixture of at least one water-miscible organic solvent selected from ethanol, isopropyl alcohol, methanol and butanol, with at least one other water-miscible organic solvent,such that, on addition of excess water, the composition spontaneously forms vesicles or liposomes, the proportion by weight of a) to b) being from 40:1 to 1:20.
7. An aerosol composition comprising in a volatile liquid propellant:-
 - a) at least one membrane lipid,
 - b) at least one water-miscible organic solvent, and optionally
 - c) up to 40%, by weight on the combined weights of a), b) and c), of water,such that, on coming into contact with excess water, the composition spontaneously forms vesicles or liposomes, the proportion by weight of a) to b) being from 40:1 to 1:20.
8. A pro-liposome composition as claimed in any of claims 1 to 4, wherein from 5% to 40% by weight of water is present as component c).
9. A composition as claimed in any one of claims 1 to 8, wherein there is also present up to 25% of a fatty acid ester.
10. A composition as claimed in any one of claims 1 to 9, wherein the volatile water-miscible organic solvent is ethanol.
11. A composition as claimed in any one of claims 1 to 10, wherein cholesterol is also present together with one or both of stearylamine and cetyl phosphate.
12. A composition as claimed in any one of claims 1 to 11, wherein there is also present a biologically active compound.
13. A pro-liposome composition as claimed in claim 1 or claim 2, wherein the proportion of component a) is from 35% to 55% by weight, the proportion of component b) is from 30% to 55% by weight and the proportion of water as component c) is from 5% to 20% by weight.
14. An aerosol composition as claimed in any one of claims 7 and claims 9 to 12 when dependent thereon, wherein the proportion by weight of component a) to component b) is from 1:2 to 1:10.
15. A method of making an aqueous dispersion of liposomes which comprises mixing a composition as claimed in any one of claims 1 to 6, and claims 9 to 13 when dependent thereon, with excess water.
16. A method as claimed in claim 15, wherein the excess water is added at elevated temperature and the liposomes are formed upon subsequent cooling to ambient temperature.
17. A method as claimed in claim 15 or 16, wherein the water is mixed in two stages.

18. A method as claimed in claim 15, 16 or 17, wherein the water contains a biologically active compound that becomes entrapped in the membrane lipid, the biologically active compound optionally comprising a medicament, protein, enzyme, hormone, vitamin or marker compound.
- 5 19. A method as claimed in claim 15 and claims 17 and 18 when dependent thereon, wherein the mixing step is performed in vitro.
20. A method as claimed in any of claims 15 to 19, wherein the composition is agitated as it is mixed with water.
- 10 21. A method as claimed in claim 15, wherein the mixing step is performed in vivo.
22. A method of making an aqueous dispersion of liposomes which comprises spraying an aerosol composition as claimed in claim 7, or any one of claims 9 to 12 and 14 when dependent thereon, so
15 that it comes into contact with excess water.
23. A method as claimed in any one of claims 15 to 22, wherein the resultant aqueous dispersion of liposomes is extruded through a membrane filter.
- 20 24. A method as claimed in any of claims 15 to 23, when used to make a liposome dispersion comprising liposomes formed of membrane lipid which have diameters within the range of 0.1 to 2.5 μm (microns) and contain at least 2 ml of entrapped aqueous fluid per gram of the lipid, characterized by the presence in the dispersion of detectable quantities of at least one water-miscible organic solvent.
- 25 25. A composition as claimed in any one of claims 1 to 14, in the form of an aerosol of droplets having a weight average diameter below 8 μm (microns).

Claims for the following Contracting States : AT, BE, NL, SE, CH

- 30 1. A pro-liposome composition comprising a uniform mixture of:-
 - a) at least one membrane lipid,
 - b) at least one water-miscible organic solvent, and optionally
 - c) an amount of water,such that, on addition of excess water, the composition spontaneously forms vesicles or liposomes, the
35 proportion by weight of a) to b) being from 40:1 to 1:20.
2. A composition according to claim 1, containing a small amount of water resulting in formation of a network or stack of expanded bilayers, the composition reorganising into liposomes on addition of excess water.
- 40 3. A composition according to claim 1, containing water resulting in the formation of bilayers with water inclusions entrapped within the said bilayers, the composition reorganising into liposomes on addition of excess water.
- 45 4. A pro-liposome composition as claimed in claim 1, wherein from 5% to 40% by weight of water is present as component c).
5. A pro-liposome composition comprising a uniform mixture of:-
 - a) at least one membrane lipid,
 - 50 b) at least one water-miscible organic solvent,the proportion by weight of a) to b) being from 40:1 to 1:20, which upon the addition of a small amount of water forms a network or stack of expanded bilayers, addition of further water leading to the entrapment of water inclusions within the said bilayers and addition of excess water and optionally agitation leading to the breakdown of this structure to form vesicles or liposomes.
- 55 6. An aerosol composition comprising in a volatile liquid propellant:-
 - a) at least one membrane lipid,
 - b) at least one water-miscible organic solvent, and optionally

- c) up to 40%, by weight on the combined weights of a), b) and c), of water, such that, on coming into contact with excess water, the composition spontaneously forms vesicles or liposomes, the proportion of weight of a) to b) being from 40:1 to 1:20.
- 5 7. A composition as claimed in any one of claims 1 to 6, wherein there is also present up to 25% of a fatty acid ester.
 8. A composition as claimed in any one of claims 1 to 7, wherein component b) is ethanol or propylene glycol.
 - 10 9. A composition as claimed in any one of claims 1 to 8, wherein cholesterol is also present together with one or both of stearylamine and cetyl phosphate.
 - 15 10. A composition as claimed in any one of claims 1 to 8, wherein there is also present a biologically active compound.
 - 20 11. A composition as claimed in claim 1, wherein the proportion of component a) is from 35% to 55% by weight, the proportion of component b) is from 30% to 55% by weight and the proportion of water as component c) is from 5% to 20% by weight.
 - 25 12. An aerosol composition as claimed in any one of claims 6 and claims 7 to 10 when dependent thereon, wherein the proportion by weight of component a) to component b) is from 1:2 to 1:10.
 13. A method of making an aqueous dispersion of liposomes which comprises mixing a composition as claimed in any one of claims 1 to 5, and claims 7 to 11 when dependent thereon, with excess water.
 14. A method as claimed in claim 13, wherein the excess water is added at elevated temperature and the liposomes are formed upon subsequent cooling to ambient temperature.
 - 30 15. A method as claimed in claim 13, or claim 14, wherein the water is mixed in two stages.
 16. A method as claimed in claim 13, 14 or 15, wherein the water contains a biologically active compound that becomes entrapped in the membrane lipid, the biologically active compound optionally comprising a medicament, protein, enzyme, hormone, vitamin or marker compound.
 - 35 17. A method as claimed in claim 13, wherein the mixing step is performed in vitro.
 18. A method as claimed in any of claims 13 to 16, wherein the composition is agitated as it is mixed with water.
 - 40 19. A method as claimed in claim 13, wherein the mixing step is performed in vivo.
 20. A method of making an aqueous dispersion of liposomes which comprises spraying an aerosol composition as claimed in claim 6, or any one of claims 7 to 10 and 12 when dependent thereon, so that it comes into contact with excess water.
 - 45 21. A method as claimed in any one of claims 15 to 19, wherein the resultant aqueous dispersion of liposomes is extruded through a membrane filter.
 - 50 22. A method as claimed in any of claims 13 to 21, when used to make an aqueous liposome dispersion comprising liposomes formed of membrane lipid which have diameters within the range of 0.1 to 2.5 microns and contain at least 2 ml of entrapped aqueous fluid per gram of the lipid, characterized by the presence in the aqueous dispersion of detectable quantities of a water-miscible organic solvent.
 - 55 23. A composition as claimed in any one of claims 1 to 12, in the form of an aerosol of droplets having a weight average diameter below 8 μm (microns).

Revendications

Revendications pour les Etats contractants suivants : DE, FR, GB, IT

- 5 1. Composition pro-liposome comprenant un mélange uniforme de :
 - a) au moins un lipide membraneux,
 - b) au moins un solvant organique miscible à l'eau choisi à partir d'éthanol, d'alcool isopropylique, de méthanol et de butanol et, facultativement,
 - c) une quantité d'eau,
- 10 caractérisée en ce que, à l'addition d'un excès d'eau, la composition forme spontanément des vésicules ou liposomes, la proportion par poids de a) par rapport à b) étant de 40:1 à 1:20.
2. Composition pro-liposome comprenant un mélange uniforme de :
 - a) au moins un lipide membraneux,
 - 15 b) au moins un solvant organique miscible à l'eau,
 - c) une quantité d'eau en une quantité inférieure à celle qui résulte en la formation de liposomes,
- caractérisée en ce que, à l'addition d'un excès d'eau, la composition se réorganise en vésicules ou liposomes, la proportion par poids de a) par rapport à b) étant de 40:1 à 1:20.
- 20 3. Composition qui, selon la revendication 1 ou 2, est caractérisée en ce que, contenant une petite quantité d'eau qui résulte en la formation d'un réseau ou d'un amoncellement de doubles couches dilatées, la composition se réorganise sous forme de liposomes à l'addition d'un excès d'eau.
4. Composition qui, selon la revendication 1, est caractérisée en ce que, contenant de l'eau qui résulte en
- 25 la formation de doubles couches avec des inclusions d'eau prises au piège à l'intérieur desdites doubles couches, la composition se réorganise en liposomes à l'addition d'un excès d'eau.
5. Composition pro-liposome comprenant un mélange uniforme de :
 - a) au moins un lipide membraneux et
 - 30 b) au moins un solvant organique miscible à l'eau choisi à partir d'éthanol, d'alcool isopropylique, de méthanol et de butanol, la proportion par poids de a) par rapport à b) étant de 40:1 à 1:20,
- caractérisée en ce qu'à l'addition d'une petite quantité d'eau, elle forme un réseau ou amoncellement de doubles couches dilatées, l'addition d'eau supplémentaire entraînant la prise au piège
- d'inclusions d'eau à l'intérieur desdites doubles couches et l'addition d'un excès d'eau avec
- 35 agitation facultative conduisant à la rupture de cette structure pour former des vésicules ou liposomes.
6. Composition pro-liposome de forme anhydre comprenant un mélange uniforme de :
 - a) au moins un lipide membraneux,
 - 40 b) au moins un solvant organique miscible à l'eau choisi à partir d'éthanol, d'alcool isopropylique, de méthanol et de butanol, avec au moins un autre solvant organique miscible à l'eau, caractérisée en ce que, à l'addition d'un excès d'eau, la composition forme spontanément des vésicules ou liposomes, la proportion par poids de a) par rapport à b) étant de 40:1 à 1:20.
- 45 7. Composition aérosol comprenant, dans un liquide pulseur volatil :
 - a) au moins un lipide membraneux,
 - b) au moins un solvant organique miscible à l'eau et, facultativement,
 - c) jusqu'à 40 %, par poids sur les poids combinés de a), b) et c), d'eau,
- caractérisée en ce que, au contact avec un excès d'eau, la composition forme spontanément des
- 50 vésicules ou liposomes, la proportion de poids de a) par rapport à b) étant de 40:1 à 1:20.
8. Composition pro-liposome qui, selon l'une quelconque des revendications de 1 à 4, est caractérisée en ce que de 5% à 40 % par poids d'eau sont présents sous forme du composant c).
- 55 9. Composition qui, selon l'une quelconque des revendications de 1 à 8, est caractérisée en ce que que 25 % d'ester d'acides gras sont aussi présents.

10. Composition qui, selon l'une quelconque des revendications de 1 à 9, est caractérisée en ce que le solvant organique volatil miscible à l'eau est de l'éthanol.
- 5 11. Composition qui, selon l'une quelconque des revendications de 1 à 10, est caractérisée en ce que le cholestérol y est aussi présent avec de la stéarylamine et/ou du phosphate de céthyle.
12. Composition qui, selon l'une des revendications de 1 à 11, est caractérisée en ce qu'un composé biologiquement actif est aussi présent.
- 10 13. Composition pro-liposome qui, selon la revendication 1 ou la revendication 2, est caractérisée en ce que la proportion du composant a) est de 35 % à 55 % par poids, la proportion du composant b) est de 30 % à 55 % par poids et la proportion de l'eau en tant que composant c) est de 5 % à 20 % par poids.
- 15 14. Composition aérosol qui, selon l'une quelconque de la revendication 7 et des revendications de 9 à 12 lorsqu'elle en dépend, est caractérisée en ce que la proportion par poids du composant a) par rapport au composant b) est de 1:2 à 1:10.
- 20 15. Méthode qui, selon l'une quelconque des revendications de 1 à 6, et des revendications de 9 à 13 lorsqu'elle en dépend, est caractérisée en ce qu'elle consiste à produire une dispersion aqueuse de liposomes comprenant le mixage d'une composition avec un excès d'eau.
- 25 16. Méthode qui, selon la revendication 15, est caractérisée en ce que l'excès d'eau est ajouté à une température élevée et les liposomes sont formés lors du refroidissement ultérieur à la température ambiante.
17. Méthode qui, selon la revendication 15 ou la revendication 16, est caractérisée en ce que l'eau est mélangée en deux temps.
- 30 18. Méthode qui, selon les revendications 15, 16 ou 17, est caractérisée en ce que l'eau contient un composé biologiquement actif qui est pris au piège dans le lipide membranaux, ce composé comprenant facultativement un médicament, des protéines, des enzymes, des hormones, des vitamines ou un composé marqueur.
- 35 19. Méthode qui, selon la revendication 15 et les revendications 17 et 18 quand elle en dépend, est caractérisée en ce que la phase de mixage s'effectue in vitro.
- 40 20. Méthode qui, selon l'une quelconque des revendications de 15 à 19, est caractérisée en ce que la composition est agitée au cours du mixage avec l'eau.
21. Méthode qui, selon la revendication 15, est caractérisée en ce que la phase de mixage s'effectue in vivo.
- 45 22. Méthode qui consiste à produire une dispersion aqueuse des liposomes qui comprend la pulvérisation d'une composition aérosol selon la revendication 7, ou l'une quelconque des revendications de 9 à 12 et 14, quand elle en dépend, caractérisée en ce qu'elle entre en contact avec un excès d'eau.
- 50 23. Méthode qui, selon l'une quelconque des revendications de 15 à 22, est caractérisée en ce que la dispersion aqueuse des liposomes qui en résulte est passée par un filtre de membrane.
24. Méthode qui, selon l'une quelconque des revendications de 15 à 23, lorsqu'elle est utilisée pour produire une dispersion aqueuse des liposomes comprenant des liposomes formés de lipide membranaux qui ont un diamètre variant de 0,1 à 2,5 µm (microns) et contiennent au moins 2 ml de fluide aqueux piégé par gramme du lipide, est caractérisée par la présence dans la dispersion aqueuse de quantités détectables d'au moins un solvant organique miscible à l'eau.
- 55

25. Composition qui, selon l'une quelconque des revendications de 1 à 14, est caractérisée en ce qu'elle se présente sous la forme d'aérosol de gouttelettes qui ont un poids moyen et un diamètre inférieur à 8 μ m (microns).

5 **Revendications pour les Etats contractants suivants : AT, BE, NL, SE, CH**

1. Composition pro-liposome comprenant un mélange uniforme de :
 - a) au moins un lipide membraneux,
 - b) au moins un solvant organique miscible à l'eau et, facultativement,
 - 10 c) une quantité d'eau,
 caractérisée en ce que, à l'addition d'un excès d'eau, la composition forme spontanément des vésicules ou liposomes, les proportions par poids de a) par rapport à b) étant de 40:1 à 1:20.
- 15 2. Composition qui, selon la revendication 1, est caractérisée en ce que, contenant une petite quantité d'eau qui résulte en la formation d'un réseau ou amoncellement de doubles couches dilatées, la composition se réorganise sous forme de liposomes à l'addition d'un excès d'eau.
3. Composition qui, selon la revendication 1, est caractérisée en ce que, contenant de l'eau qui résulte en la formation de doubles couches avec des intrusions d'eau prises au piège à l'intérieur desdites
 20 doubles couches, la composition se réorganise en liposomes à l'addition d'un excès d'eau.
4. Composition pro-liposome qui, selon la revendication 1, est caractérisée en ce que de 5 à 40 % par poids d'eau sont présents sous forme du composant c).
- 25 5. Composition pro-liposome qui comprend un mélange uniforme de :
 - a) au moins un lipide membraneux et
 - b) au moins un solvant organique miscible à l'eau,
 les proportions par poids de a) par rapport à b) étant de 40:1 à 1:20, caractérisée en ce qu'à l'addition d'une petite quantité d'eau le mélange forme un réseau ou amoncellement de doubles couches
 30 dilatées, l'addition d'eau supplémentaire entraînant la prise au piège d'inclusions d'eau à l'intérieur desdites doubles couches et l'addition d'un excès d'eau avec agitation facultative conduisant à la rupture de cette structure pour former des vésicules ou liposomes.
- 35 6. Composition aérosol comprenant, dans un liquide pulseur volatil :
 - a) au moins un lipide membraneux,
 - b) au moins un solvant organique miscible à l'eau et, facultativement,
 - c) jusqu'à 40 %, par poids sur les poids combinés de a), b) et c), d'eau,
 caractérisée en ce que, au contact avec un excès d'eau, la composition forme spontanément des
 40 vésicules ou liposomes, la proportion de poids de a) par rapport à b) étant de 40:1 à 1:20.
7. Composition qui, selon l'une quelconque des revendications de 1 à 6, est caractérisée en ce que 25 % d'ester d'acides gras sont aussi présents.
8. Composition qui, selon l'une quelconque des revendications de 1 à 7, est caractérisée en ce que le
 45 composant b) est de l'éthanol ou du propylèneglycol.
9. Composition qui, selon l'une quelconque des revendications de 1 à 8, est caractérisée en ce que le cholestérol y est aussi présent avec de la stéarylamine et/ou du phosphate de céthyle.
- 50 10. Composition qui, selon l'une des revendications de 1 à 8, est caractérisée en ce qu'un composé biologiquement actif est aussi présent.
11. Composition qui, selon la revendication 1, est caractérisée en ce que la proportion du composant a) est de 35 % à 55 % par poids, la proportion du composant b) est de 30 % à 55 % par poids et la
 55 proportion de l'eau en tant que composant c) est de 5 % à 20 % par poids.

12. Composition aérosol qui, selon l'une quelconque de la revendication 6 et des revendications de 7 à 10 lorsqu'elle en dépend, est caractérisée en ce que la proportion par poids du composant a) par rapport au composant b) est de 1:2 à 1:10.
- 5 13. Méthode qui, selon l'une quelconque des revendications de 1 à 5, et des revendications de 7 à 11 lorsqu'elle en dépend, est caractérisée en ce qu'elle consiste à produire une dispersion aqueuse de liposomes comprenant le mixage d'une composition avec un excès d'eau.
- 10 14. Méthode qui, selon la revendication 13, est caractérisée en ce que l'excès d'eau est ajouté à une température élevée et les liposomes sont formés lors du refroidissement ultérieur à la température ambiante.
- 15 15. Méthode qui, selon la revendication 13 ou la revendication 14, est caractérisée en ce que l'eau est mélangée en deux temps.
- 20 16. Méthode qui, selon les revendications 13, 14 ou 15, est caractérisée en ce que l'eau contient un composé biologiquement actif pris au piège dans le lipide membraneux, ce composé biologiquement actif comprenant facultativement un médicament, des protéines, des enzymes, des hormones, des vitamines ou un composé marqueur.
- 25 17. Méthode qui, selon la revendication 13, est caractérisée en ce que la phase de mixage s'effectue in vitro.
- 30 18. Méthode qui, selon l'une quelconque des revendications de 13 à 16, est caractérisée en ce que la composition est agitée au cours du mixage avec l'eau.
- 35 19. Méthode qui, selon la revendication 13, est caractérisée en ce que la phase de mixage s'effectue in vivo.
- 40 20. Méthode qui consiste à produire une dispersion aqueuse des liposomes et qui comprend la pulvérisation d'une composition aérosol selon la revendication 6, ou l'une quelconque des revendications de 7 à 10 et 12, quand elle en dépend, caractérisée en ce qu'elle entre en contact avec l'excès d'eau.
- 45 21. Méthode qui, selon l'une quelconque des revendications de 15 à 19, est caractérisée en ce que la dispersion aqueuse des liposomes qui en résulte est passée par un filtre de membrane.
22. Méthode qui, selon l'une quelconque des revendications de 13 à 21, lorsqu'elle est utilisée pour produire une dispersion aqueuse des liposomes comprenant des liposomes formés de lipide membraneux ayant un diamètre variant de 0,1 à 2,5 microns et contenant au moins 2 ml de fluide aqueux piégé par gramme de lipide, est caractérisée par la présence dans la dispersion aqueuse de quantités détectables d'un solvant organique miscible à l'eau.
23. Composition qui, selon l'une quelconque des revendications de 1 à 12, est caractérisée en ce qu'elle se présente sous la forme d'aérosol de gouttelettes qui ont un poids moyen et un diamètre inférieur à 8 µm (microns)

Patentansprüche

Patentansprüche für folgende Vertragsstaaten : DE, FR, GB, IT

- 50 1. Pro-liposome Zusammensetzung bestehend aus einer gleichförmigen Mischung aus:
- a) wenigstens einem Membranlipid,
 - b) wenigstens einem mit Wasser mischbaren organischen Lösungsmittel wie Ethanol, Isopropylalkohol, Methanol oder Butanol, und nach Wunsch
 - 55 c) einer Menge Wasser,
- so daß in der Zusammensetzung nach Zugabe von Überschußwasser spontan Vesikel oder Liposomen gebildet werden, wobei das Gewichtsverhältnis zwischen a) und b) von 40:1 bis 1:20 beträgt.

2. Pro-liposome Zusammensetzung bestehend aus einer gleichförmigen Mischung aus:
 - a) wenigstens einem Membranlipid,
 - b) wenigstens einem mit Wasser mischbaren Lösungsmittel, und
 - c) einer Menge Wasser, die geringer ist als die, die zur Bildung von Liposomen führt, so daß die Zusammensetzung nach Zugabe von Überschußwasser zu Vesikeln oder Liposomen umgruppiert wird, wobei das Gewichtsverhältnis zwischen a) und b) von 40:1 bis 1:20 beträgt.
3. Zusammensetzung nach Anspruch 1 oder 2 mit geringem Wassergehalt, der zur Bildung eines Netzes oder Stapels von expandierten Doppelschichten führt, wobei die Zusammensetzung nach Zugabe von Überschußwasser zu Liposomen umgruppiert wird.
4. Zusammensetzung nach Anspruch mit einem Wassergehalt, der zur Bildung von Doppelschichten führt, wobei Wasser innerhalb der genannten Doppelschichten eingeschlossen wird und die Zusammensetzung nach Zugabe von Überschußwasser zu Liposomen umgruppiert wird.
5. Pro-liposome Zusammensetzung bestehend aus einer gleichförmigen Mischung aus:
 - a) wenigstens einem Membranlipid und
 - b) wenigstens einer mit Wasser mischbaren Lösung wie Ethanol, Isopropylalkohol, Methanol oder Butanol,wobei das Gewichtsverhältnis zwischen a) und b) von 40:1 bis 1:20 beträgt, die nach Zugabe einer geringen Wassermenge ein Netz oder einen Stapel von expandierten Doppelschichten bildet, wobei eine weitere Zugabe von Wasser zu Wassereinschlüssen innerhalb der genannten Doppelschichten und die Zugabe von Überschußwasser unter wahlweisem Rühren zum Zusammenbruch dieser Strukturen unter Bildung von Vesikeln oder Liposomen führt.
6. Pro-liposome Zusammensetzung in wasserfreier Form bestehend aus einer gleichförmigen Mischung aus:
 - a) wenigstens einem Membranlipid, und
 - b) wenigstens einem mit Wasser mischbaren organischen Lösungsmittel wie Ethanol, Isopropylalkohol, Methanol oder Butanol,so daß in der Zusammensetzung nach Zugabe von Überschußwasser spontan Vesikel oder Liposomen gebildet werden, wobei das Gewichtsverhältnis zwischen a) und b) von 40:1 bis 1:20 beträgt.
7. Aerosolzusammensetzung bestehend aus einem flüchtigen Flüssigtreibgas bestehend aus:
 - a) wenigstens einem Membranlipid,
 - b) wenigstens einem mit Wasser mischbaren organischen Lösungsmittel, und nach Wunsch
 - c) Wasser mit einem Gewichtsanteil von bis zu 40% der Summe der Gewichte von a), b) und c),so daß es bei einem Gewichtsverhältnis zwischen a) und b) von 40:1 bis 1:20 unter Zugabe von Überschußwasser spontan zur Bildung von Vesikeln oder Liposomen kommt.
8. Pro-liposome Zusammensetzung nach Anspruch 1 bis 4, worin Wasser mit einem Gewichtsanteil von 5 - 40% als Komponente c) präsent ist.
9. Zusammensetzung nach Anspruch 1 bis 8, worin bis zu 25% eines Fettsäureester präsent ist.
10. Zusammensetzung nach Anspruch 1 bis 9, worin es sich bei der flüchtigen wassermischbaren organischen Lösung um Ethanol handelt.
11. Zusammensetzung nach Anspruch 1 bis 10, worin Cholesterol zusammen mit Stearylamin und/oder Cetylphosphat ebenfalls vorhanden ist.
12. Zusammensetzung nach Anspruch 1 bis 11, wobei eine biologisch aktive Verbindung ebenfalls vorhanden ist.
13. Zusammensetzung nach Anspruch 1 oder 2, worin Komponente a) einen Gewichtsanteil von 35 - 55%, Komponente b) einen Gewichtsanteil von 30 - 55% und Wasser als Komponente c) einen Gewichtsanteil von 5 - 20% aufweist.

14. Aerosolzusammensetzung nach Anspruch 7 und gegebenenfalls nach den davon abhängigen Ansprüchen 9 bis 12, mit einem Gewichtsverhältnis zwischen Komponente a) und Komponente b) von 1:2 bis 1:10.
- 5 15. Verfahren zur Herstellung einer wäßrigen Dispersion von Liposomen unter Zugabe von Überschußwasser, bestehend aus einer Zusammensetzung nach Anspruch 1 bis 6 und gegebenenfalls den davon abhängigen Ansprüchen 9 bis 13.
16. Verfahren nach Anspruch 15, worin das Überschußwasser bei erhöhter Temperatur zugegeben wird und es zur Liposomenbildung während der anschließenden Abkühlung auf Umgebungstemperatur kommt.
- 10 17. Verfahren nach Anspruch 15 oder 16, worin das Wasser in zwei Phasen zugegeben wird.
- 15 18. Verfahren nach Anspruch 15, 16 oder 17, worin das Wasser eine biologisch aktive Verbindung enthält, wahlweise bestehend aus einem Medikament, Protein, Enzym, Hormon, Vitamin oder Markersubstanz, die vom Membranlipid eingeschlossen wird.
19. Verfahren nach Anspruch 15 und gegebenenfalls den davon abhängenden Ansprüchen 17 und 18, worin die Mischphase im Reagenzglas ausgeführt wird.
- 20 20. Verfahren nach Anspruch 15 bis 19, worin das Wasser unter Rühren der Zusammensetzung zugegeben wird.
- 25 21. Verfahren nach Anspruch 15, wobei die Mischphase in vivo ausgeführt wird.
22. Verfahren zur Herstellung einer wäßrigen Dispersion von Liposomen, bestehend aus einer aerosolen Zusammensetzung nach Anspruch 7 oder gegebenenfalls nach Anspruch 9 bis 12 und 14, unter Zugabe von Überschußwasser.
- 30 23. Verfahren nach Anspruch 15 bis 22, wobei die resultierende wäßrige Liposomendispersion durch einen Membranfilter extrudiert wird.
24. Verfahren nach Anspruch 15 bis 23, zur Herstellung einer wäßrigen Liposomendispersion bestehend aus membranlipidbasierenden Liposomen mit einem Durchmesser von 0,1 bis 2,5 µm und wenigstens 2 ml an eingeschlossener wäßriger Flüssigkeit pro Gramm des Lipid, dadurch gekennzeichnet, daß in der wäßrigen Dispersion erfaßbare Mengen an wassermischbarer organischer Lösung vorhanden sind.
- 35 25. Zusammensetzung nach Anspruch 1 bis 14, in Form eines Aerosols von Tröpfchen, mit einem durchschnittlichen Gewicht von 8 µm.
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Patentansprüche für folgende Vertragsstaaten : AT, BE, NL, SE, CH

1. Pro-liposome Zusammensetzung bestehend aus einer gleichförmigen Mischung aus:
45 a) wenigstens einem Membranlipid,
b) wenigstens einem mit Wasser mischbaren organischen Lösungsmittel, und nach Wunsch
c) einer Menge Wasser,
so daß nach Zugabe von Überschußwasser in der Zusammensetzung spontan Vesikel oder Liposomen gebildet werden, wobei das Gewichtsverhältnis zwischen a) und b) von 40:1 bis 1:20 beträgt.
- 50 2. Zusammensetzung nach Anspruch 1 mit geringem Wassergehalt, der zur Bildung eines Netzes oder Stapels von expandierten Doppelschichten führt, wobei die Zusammensetzung nach Zugabe von Überschußwasser zu Liposomen umgruppiert wird.
- 55 3. Zusammensetzung nach Anspruch 1 mit einem Wassergehalt, der zur Bildung von Doppelschichten führt, wobei Wasser innerhalb der genannten Doppelschichten eingeschlossen wird und die Zusammensetzung nach Zugabe von Überschußwasser zu Liposomen umgruppiert wird.

4. Pro-liposome Zusammensetzung nach Anspruch 1, wobei 5 - 40 Gew.-% Wasser als Komponente c) vorhanden ist.
5. Pro-liposome Zusammensetzung bestehend aus einer gleichförmigen Mischung aus:
 - a) wenigstens einem Membranlipid,
 - b) wenigstens einem mit Wasser mischbaren organischen Lösungsmittel,wobei das Gewichtsverhältnis zwischen a) und b) von 40:1 bis 1:20 beträgt, die unter Zugabe einer geringen Wassermenge ein Netz oder einen Stapel von expandierten Doppelschichten bildet, wobei eine weitere Zugabe von Wasser zum Einschluß von Wasser innerhalb der genannten Doppelschichten und die Zugabe von Überschußwasser unter wahlweisem Rühren zum Abbau dieser Strukturen unter Bildung von Vesikeln oder Liposomen führt.
6. Aerosolzusammensetzung bestehend aus einem flüchtigen Flüssigtreibgas bestehend aus:
 - a) wenigstens einem Membranlipid,
 - b) wenigstens einem mit Wasser mischbaren organischen Lösungsmittel, und nach Wunsch
 - c) Wasser mit einem Gewichtsanteil von bis zu 40% der Summe der Gewichte von a), b) und c),so daß bei einem Gewichtsverhältnis zwischen a) und b) von 40:1 bis 1:20 nach Zugabe von Überschußwasser spontan Vesikel oder Liposomengebildet werden.
7. Zusammensetzung nach einem der Ansprüche 1 bis 6, wobei bis zu 25% eines Fettsäureesters vorhanden sind.
8. Zusammensetzung nach einem der Ansprüche 1 bis 7, wobei die Komponente b) aus Ethanol oder Propylenglycol besteht.
9. Zusammensetzung nach einem der Ansprüche 1 bis 8, wobei auch Cholesterol zusammen mit Stearylamin und/oder Cetylphosphat vorhanden ist.
10. Zusammensetzung nach einem der Ansprüche 1 bis 8, wobei eine biologisch aktive Verbindung ebenfalls vorhanden ist.
11. Zusammensetzung nach Anspruch 1, wobei der Anteil von Komponente a) 35 - 55 Gew.-%, der von Komponente b) 30 - 55 Gew.-% und der von Komponente c) 5 - 20 Gew.-% beträgt.
12. Aerosolzusammensetzung nach einem der Ansprüche 6 und der davon abhängigen Ansprüche 7 bis 10, wobei das Gewichtsverhältnis zwischen Komponente a) und Komponente b) von 1:2 bis 1:10 beträgt.
13. Verfahren zur Herstellung einer wäßrigen Dispersion von Liposomen, durch Mischen einer Zusammensetzung nach einem der Ansprüche 1 bis 5 und der davon abhängigen Ansprüche 7 bis 11 mit Überschußwasser.
14. Verfahren nach Anspruch 13, wobei das Überschußwasser bei erhöhter Temperatur zugegeben wird und die Liposomen nach der anschließenden Abkühlung auf Umgebungstemperatur gebildet werden.
15. Verfahren nach Anspruch 13 oder 14, wobei das Wasser in zwei Phasen zugemischt wird.
16. Verfahren nach Anspruch 13, 14 oder 15, wobei das Wasser eine biologisch aktive Verbindung enthält, die je nach Wunsch ein Medikament, Protein, Enzym, Hormon, Vitamin oder eine Markersubstanz aufweisen kann, die vom Membranlipid eingeschlossen wird.
17. Verfahren nach Anspruch 13, wobei die Mischphase im Reagenzglas ausgeführt wird.
18. Verfahren nach einem der Ansprüche 13 bis 16, wobei das Wasser unter Rühren der Zusammensetzung zugemischt wird.
19. Verfahren nach Anspruch 13, wobei die Mischphase in vivo ausgeführt wird.

20. Verfahren zur Herstellung einer wäßrigen Dispersion von Liposomen, durch Versprühen einer Aerosol-
zusammensetzung nach Anspruch 6 oder einem der davon abhängigen Ansprüche 7 bis 10 und 12, so
daß diese in Kontakt mit Überschußwasser kommt.
- 5 21. Verfahren nach einem der Ansprüche 15 bis 19, wobei die resultierende wäßrige Liposomendispersion
durch einen Membranfilter extrudiert wird.
22. Verfahren nach einem der Ansprüche 13 bis 21 zur Herstellung einer wäßrigen Liposomendispersion, die
Liposomen aus Membranlipid mit Durchmessern von 0,1 bis 2,5 Mikron und wenigstens 2 ml an
10 eingeschlossener wäßriger Flüssigkeit pro Gramm des Lipids aufweisen, dadurch gekennzeichnet, daß
in der wäßrigen Dispersion erfaßbare Mengen an wassermischbarer organischer Lösung vorhanden
sind.
23. Zusammensetzung nach einem der Ansprüche 1 bis 12 in Form eines Tröpfchenaerosols mit einem
15 durchschnittlichen Gewicht von unter 8 μm .

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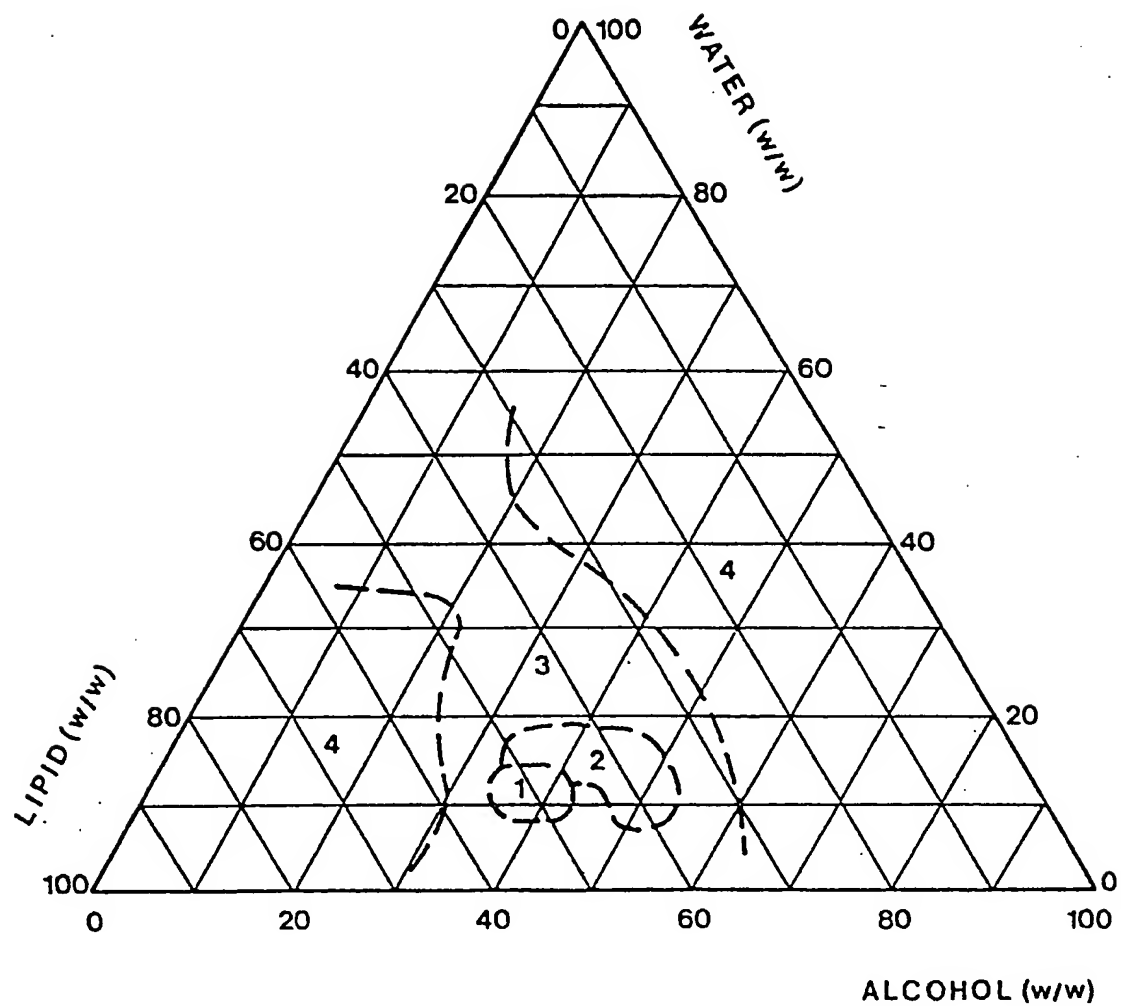
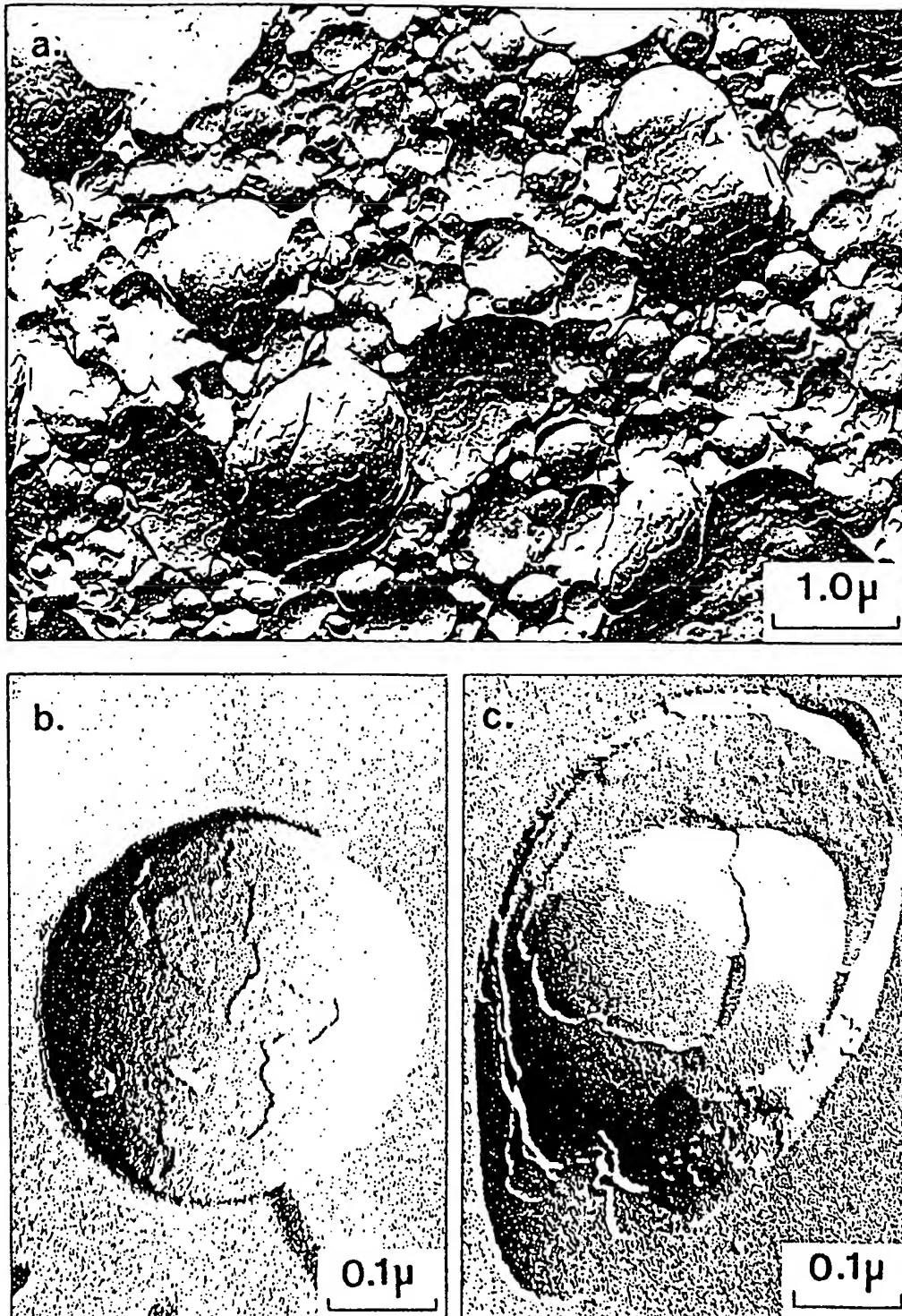


FIG. 1

*FIG. 2*

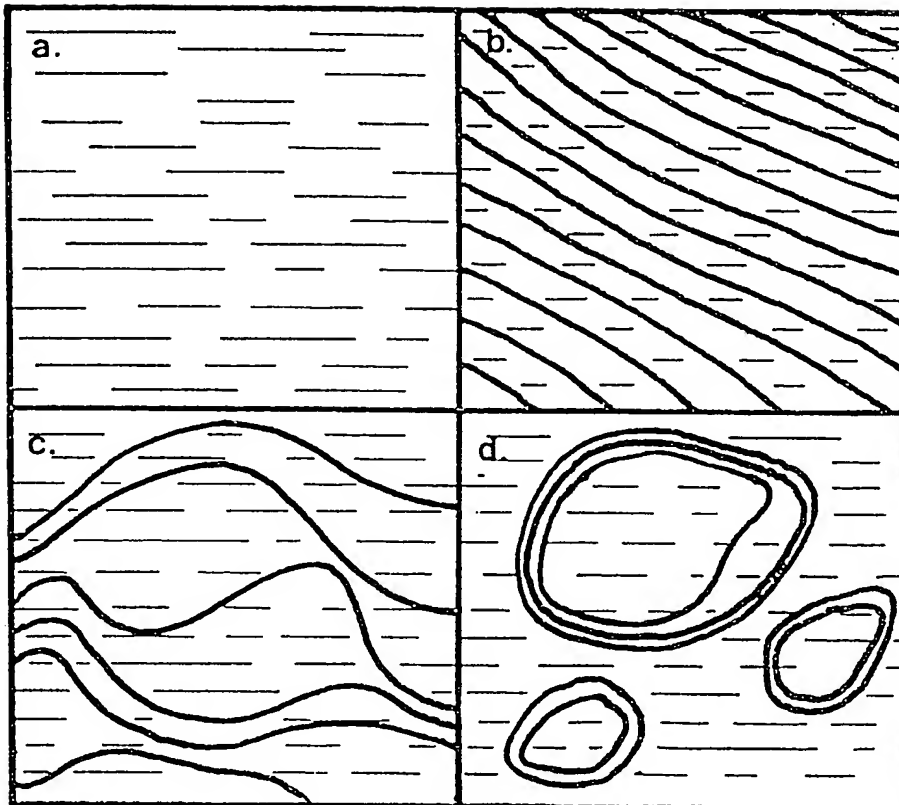


FIG. 3